Development of an Air-Deployable Ocean Profiler

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LONG-TERM GOALS

Our goal is to develop an air-deployable ocean profiler (ADOP) that will make it feasible to rapidly deploy sustainable upper-ocean observing arrays.

OBJECTIVES

This project's objective was to design and build an ADOP to be deployed from aircraft through an A-sized (4.875 inch diameter, 36 inches long) sonobuoy tube. The performance goal was 200 dives to 400 m depth with a scientific payload of 1.5 kg using Iridium communication and GPS locating at the surface. ADOP was intended to be the basis for air-deployed arrays that establish persistent area surveillance over regions O(100 km) on a side without post-deployment maintenance.

APPROACH

Our design approach is based on variable-buoyancy ocean vehicles developed previously at Scripps. This provided a basis for dividing the design of ADOP into the following related tasks:

- select a buoyancy engine with minimum volume and weight that provides efficient electrical to mechanical energy conversion;
- select an air-drag device (e.g. parachute) to limit the shock-load hitting the ocean surface and quickly release it from the float;
- provide an antenna with minimum packing volume and above-surface volume (to minimize pumping) for reliable Iridium/GPS communication;
- determinine if an external "damping" device is needed to limit vertical oscillations of the float in a seaway in order to achieve reliable communication and then provide any device needed;
- provide a flexible central controller so new sensor sytems can easily be accommodated;
- minimize the expense to manufacture in numbers of 100 or more;
- minimize ADOP weight and maximize payload capacity for batteries and sensors.

The initial design was based on using the Littoral Ambient Spectral Recorder (LASR), which detects and analyzes ambient sound, as a scientific payload but our goal is a general-use platform.

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WORK COMPLETED

We have completed design of ADOP, built four units, tested them in our laboratory ocean simulator, carried out successful tests of radio communication in a seaway, and completed at-sea tests of cycling performance and acoustic characteristics with a LASR on board. We have designed an air-deployment configuration using a parachute of about 0.8 m diameter and hope to begin air-deployment tests with remaining funds. The design has a operating depth of 400 m and maximum depth of 500 m. It carries 30 C-sized Alkaline batteries which can power 200 dives to 300 m by changing volume by up to 215 cc; lithium batteries would more than double this lifetime. The float mass is 8.6 kg (11 kg ready for air deployment) and ascends in the ocean at 15-40 cm/s. Locating is by GPS and Iridium SBD transmits/receives data.

Buoyancy engine. The buoyancy engine uses a DC gear-motor driving a lead-screw and ball-jack to move the teflon-coated piston whose outer surface is exposed to seawater; it pumps about 0.6 cc/s. Laboratory tests include 2000 cycles against a 500 dbar pressure at 20^{o}C and 4^{o}C. The pump/motor combinatin has 45% energy efficiency. Long term tests of corrosion in salt water showed no damage to the piston.

Electronics. Our electronic design emphasizes flexibility rather than trying to accommodate all possible eventual uses. The Persistor CF2 central controller interfaces with Iridium and GPS units, controls all float functions, polls some sensors, and provides serial communication with “guest” sensor packages. A 12-bit Analog-to-Digital (A/D) converter senses float functions while four channels of 16-bit A/D conversion are provided for pressure and temperature sensors and “guest” analog channels.

Antenna. For air-deployed antennas, pre-launch packing volume, out of water volume (to minimize buoyancy loss), reliabilty under pressure cycling, and radiation pattern are key. ADOP’s ‘tapemeasure’ antenna unfolds into a stable vertical staff supporting a horizontal dipole tuned for both Iridium and GPS. Surface-communication tests proved performance in a seaway and pressure testing proved durability under pressure cycling. Many vertical-cylinder floats use a “damping disk” to reduce vertical oscillations relative to the surface to improve communication. Extensive surface communication tests in a seaway showed only a small increase in performance of ADOP, so we have abandoned a drag-plate in favor of reliability and simplicity.

Air deployment. For air deployment, fall velocity must be limited to minimize shock-loads hitting the sea surface. This must be done while also limiting the shock as the drag device deploys immediately after leaving the aircraft and minimizing the pre-deployment packing volume. Field tests and simulations led to selecting a small parachute over rotating vanes or ribbon streamers. A fall-rate of 14 m/s can be achieved with a parachute that packs in a 220 cm^3 volume. Because the deployment shock depends on aircraft velocity, the optimal parachute diameter also depends on this speed.

After a float falls to the sea surface, a parachute threatens its operation. ADOP air-deploys inside a steel cannister to which the parachute is attached. When the float sense water contact, the buoyancy-control piston actuates release of the float from the cannister and the float sinks into operation. The shock loads found in drops into a local pool were used to design the release mechanism.

System architecture. Figure 1 illustrates the assembled float. The antenna is in its “unfolded” configuration. The buoyancy-engine piston protrudes through the lower endcap while sensors (e.g. the

LASR transducer) are mounted to the upper endcap. The pump is surrounded by the C-cell alkaline battery pack. The science payload and duration could be expanded by using lithium batteries

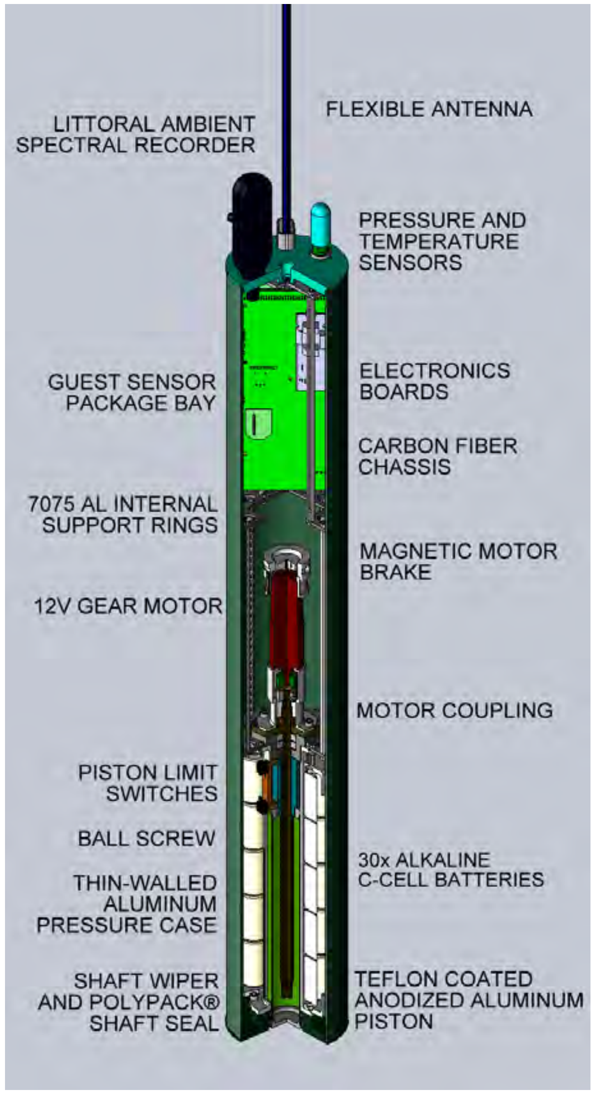

Figure 1. The internal structure of the ADOP. Various sub-assemblies are labeled.

RESULTS

Design of the float is complete, it was extensively tested in laboratory simulations of at-sea conditions, and it has undergone two fully successful depth-cycling tests at sea. A multi-month test with surface-only models quantified the effects on communication of sea-state, antenna height, and of a drag-plate to dampen vertical oscillations. In one field trial the LASR recorded acoustic data over 44 profiles to 300 m; acoustic results will be reported by Eric Terrill.   Three prototype ADOPs stand ready for use in a 2012 field trial where they will be deployed from a ship. Tests of the air-deployment system are yet to be completed

IMPACT/APPLICATIONS

We hope that a general-use profiling float executing 200 cycles to 500 m, supporting GPS and Iridium communication, with payload capacity of O(1 kg), and capable of air-deployment through an A-size sonobuoy tube will find broad use in Navy research and operations.

RELATED PROJECT

This effort is related to the project “Expanded Development of a Float for the Measurement of Ambient Noise and Air-Sea Interaction Processes” supported by grant N00014-03-1-0746 awarded to Eric J. Terrill of Scripps Institution of Oceanography.